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Recommendation for an interface system for product related computer data to enhance the Engineering Change Order/ Preliminary Change Order function

Patrick B. McPhee

RECOMMENDATION FOR AN INTERFACE SYSTEM FOR PRODUCT RELATED COMPUTER DATA TO ENHANCE THE ENGINEERING CHANGE ORDER/PRELIMINARY CHANGE ORDER FUNCTION

BY

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Patrick B. McPhee

Date: 5.16.93

To Laura, Tiffany and my Parents
for standing behind me and supporting me
during the preparation and completion of this work.

ABSTRACT

The following document will explore product and information integration by demonstrating the potential economic, strategic, and technical benefits attainable in the Engineering Change Order/Preliminary Change Order function. Information is the foundation of today's corporate enterprise. An organization's success can depend on how effectively it identifies, manages and uses its information. As an organization grows or becomes more complex, the infrastructure of information becomes more complex. The management and distribution of information corporation wide becomes a key element in the strategic position of the organization in its given market.

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LIST OF ABBREVIATIONS

BOM - Bill of Materials

CAD - Computer Aided Design

CALS - Computer-aided Acquisition and Logistics Support

ECO - Engineering Change Order

EDI Electronic Data Interchange

E-mail Electronic Mail

GUI - Graphical User Interface

ISO - International Standards Organization

ISV - Independent Software Vendor

LAN Local Area Network

MRP - Material Requirement Planning

PC - Personal Computer

PCO - Preliminary Change Order

PDM Product Data Management

PIM - Product Information Management

QES - Quality Education System

SGML - Standard Generalized Markup Language

VAN Value Added Network

CHAPTER 1
INTRODUCTION

PURPOSE

This research is being conducted to investigate and/or develop a recommendation for system(s) of interfacing multiple forms of product related computer data between multiple facility locations on existing hardware and platforms to enhance the Engineering Change Order/Preliminary Change Order (ECO/PCO) functions. Due to the nature of rapid development cycles involved with computers and computer related products, the availability and management of information plays a key role in developing and maintaining a customer base. The corporate enterprise can save time and money and gain quality in the development and manufacturing of a product through the interfacing of product-related computer data.

DELIMITATIONS

- This study will be limited to those software packages or systems (or attributes of such systems) developed to interface different forms of computer generated data.
- This will not be an extensive study of transfer systems such as Local Area Networks (LAN), telecommunication packages, or Network File System (NFS) systems although they may be briefly described as support functions to the interface systems.
- This study will only encompass the ECO/PCO functions of a single computer manufacturing company.
- Time will also be a factor as this study is being conducted to enhance a corporate project which has an established completion date.

THE IMPORTANCE OF THE STUDY

This study is being conducted for the following reasons:

- It was determined that during the development and/or manufacturing of a product, a single ECO can generate up to 9000 pieces of paper.[1]
- Estimated Processing Costs per ECO/PCO of $671.00. Total pieces of paper generated by Central Records for the first quarter - 276,000 at a cost of $4,565.00.[2,3]
- An average of 52 ECO/PCOs per month are generated.[4]
- The current ECO/PCO process can take up to 2 months to complete, with an average of 4-6 weeks.[5]
- To improve the "Time To Market" along with improvements to the product.[6]
- To insure the company fits the definition of a "World Class Support Organization".[7]
- To improve the Material Requirement Planning (MRP) system.[8]

Information is the foundation of today's corporate enterprise. An organization's success can depend on how effectively it identifies, manages and uses its information. As an organization grows or becomes more complex, the infrastructure of information becomes more complex. The management and distribution of information, corporation wide, becomes a key element in the strategic position of the organization in its given market. However, information lies scattered amongst diverse applications in a typical organization.[9]

In the '80's and '90s much attention was paid to information technology, or the creation of information, and its advantages in automating tasks. Organizations, such as the military have also made attempts at information sharing on a global approach, introducing programs such as Computer-aided Acquisition and Logistic Support (CALS) which utilizes Standard Generalized Markup Language (SGML) as an information or data format. This allows computer-generated data to be viewed on many different forms of computer equipment. Another form of information sharing is Electronic Data

Interchange (EDI). EDI is another attempt to share information electronically, or without "paper" generation aimed at the shipment, receipt, and billing for product or services. Also, today's manufacturing and/or development techniques have progressed toward an approach to engineering known as Concurrent Engineering. Information sharing is an essential element in the successful use of Concurrent Engineering practices.

Although programs and techniques are being developed for information "sharing", companies are still saddled with ineffective technical information management. This impedes any potential for growth by slowing down organizations within the corporate enterprise. In today's economy, cost cutting measures demand more efficient use of corporate resources and information.[10]

Currently, most companies generate some form of computer-generated data which takes the form of documentation for distribution or review. Some common forms of this documentation are:

- Product Design Drawings
- Specifications
- Manufacturing Instructions
- Bill of Materials (BOM)
- Equipment Configurations
- Test Certificates
- Analysis & Test Data/Reports
- Correspondence
- Service & Maintenance Manuals
- Quality & Safety Inspection Procedures/Certification

These documents are often prepared with a diverse range of sophisticated software applications including Computer Aided Design (CAD), word processing and desktop publishing,all of which have significantly reduced the time for individual tasks. Also, personal computers and workstations have proliferated throughout the work environment, each contributing to the growing mass of largely unmanaged documents or

information. Some typical forms of the hardware utilized to create the information/ documentation are:

- Personal Computers such as IBM P.C.'s and Clones, Macintosh Computers
- Workstations such as Sun Sparc Stations, Intergraph Workstations
- Mainframe systems with X-window terminals such as Encore Computer Corporation, Digital Equipment, Hewlett Packard or IBM.

Each of these different types of hardware have different ways of performing tasks called operating systems or platforms. A platform or operating system is the way a computer calculates an expected response from a command whether the response be strictly visual as text, some form of graphic, or audio, or any combination of the three. The problem lies in the differences: a simple command on one platform may be totally unrecognizable on another platform.

Most of today's software applications currently utilized on these different types of platforms are user-friendly applications with a "Windowing" look based on a graphical format called GUI's (Graphical User Interfaces, See Figure 1). This enables employees to quickly learn and use the software in creating documentation and allows the users of different platforms to utilize unfamiliar applications as the "Look" of commands are similar. This is accomplished with such windowing standards as Microsoft Windows, OS2 desktop and the Macintosh for the P.C., or Open Look and Motif environments for the X-Window UNIX environments.

Advances in computer networking has also dramatically increased productivity within corporate organizations. Networking has progressed to the point where virtually any computer can be connected to any other computer.[11] This has made sharing or transfer of computer-generated data between organizations or workgroups more efficient

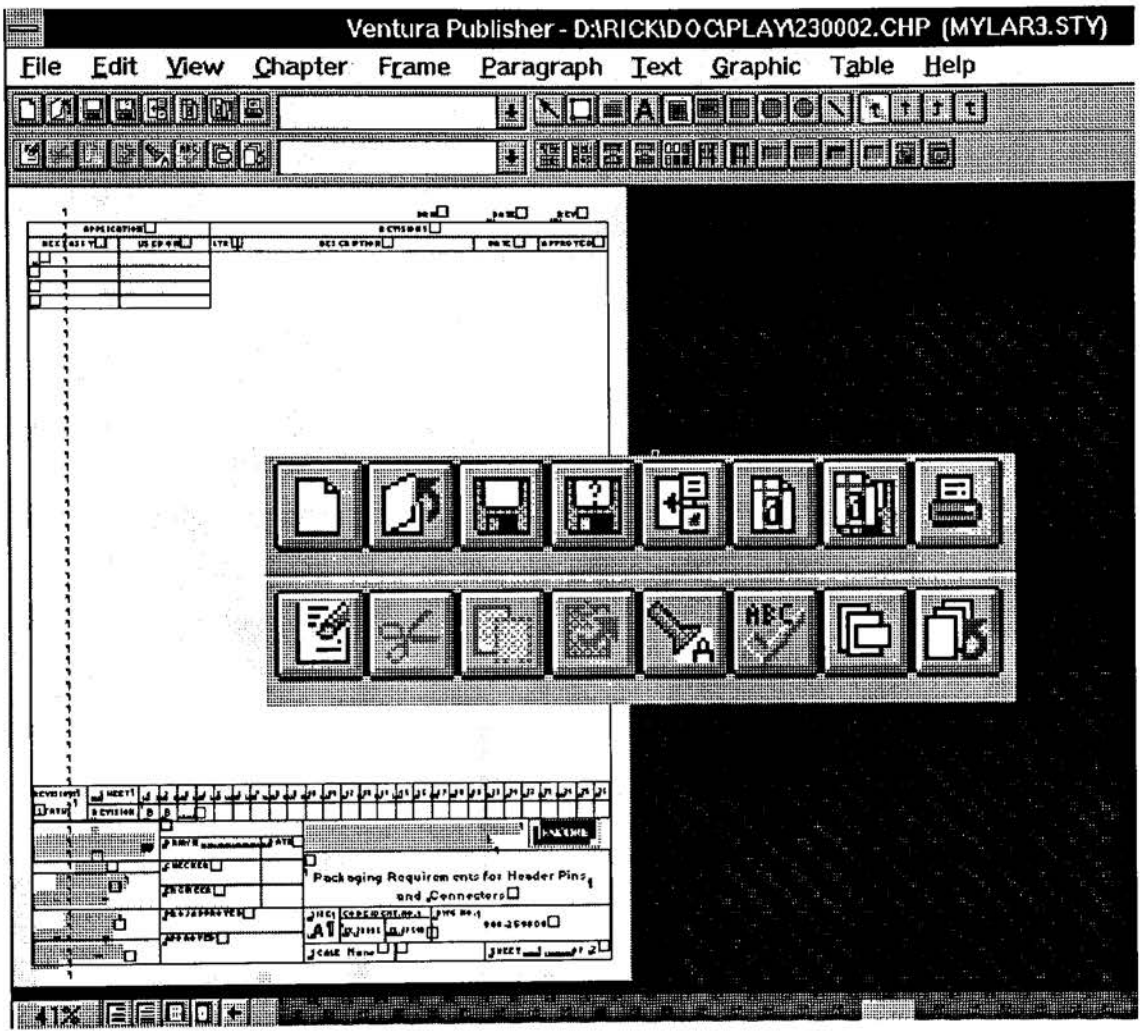

Figure 1. Software Application Utilizing Graphical User Interfaces (GUI's)[12]

and invisible to the user. However, overall product development time has not been significantly reduced due to the difficulty in management, distributing and network-wide coordination of all the different formats of vital information. Some of the different formats are listed in the following table (see Table 1).

The printed document is often the by-product of such sophisticated programs, hardware and networking systems. Cut off from its information source, the printed document represents a dead end in the information flow because the data has no link to the electronic database. The information may change at each step of creating a document. The further removed from the original source of information, the greater the risk of erroneous data. The quality of product or process can deteriorate rapidly by utilizing this data.[13]

Table 1. Various Computer Data File Formats

Application	File Extensions
Amiga ILBB	*.IFF
ASCII Text	*.TXT
AT&T Group 4	*.ATT
AutoCAD	*.DXF
CALS Raster	*.CAL
CompuServe	*.GIF
Data Beam	*.DBX
Dr. Halo	*.CUT
Fax Type	*.Type
GEM Image	*.IMG
GEM Metafile	*.GEM
HP Laserjet	*.PCL
HP Plotter	*.HPGL
IBM GOCA	*.GCA
Inset Systems	*.IGF
Inset Systems	*.PIX
Kofax Group 4	*.KFX
Lotus	*.PIC
MacPaint	*.MAC
Macintosh Pict	*.PCT
Metafile	*.CGM
Micrografix Draw	*.DRW
Microsoft Paint	*.MSD
PC Paint	*.PCX
Postscript	*.EPS
Storyboard	*.SBP
TEK. Plot 10	*.PID
TIFF	*.TIF
Truevision	*.TGA
WICAT	*.GED
Win3/OS2 Bitmap	*.BMP
Windows Metafile	*.WMF
Word Perfect	*.WPG

This data in the form of documentation can and is being used in today's corporate structures made up of independent islands of information such as (See Figure 2):

- Shop Floor
- Production Planning
- Project Planning
- Information System Departments
- Manufacturing Engineering
- Product Development
- Customer Service Departments
- Marketing and Sales

Ask any person in business what are the three key performance variables that affect the success or failure of an enterprise and they will answer Time, Cost and Quality. The accurate, rapid and controlled communication of technical information throughout these organizations and to your outside organizations is critical to providing a cost-competitive product and quality production operation[14]. This is the basis for the development of concepts such as Product Information Management (PIM), Product Data Management(PDM), as well as other concepts all under the title of "Information Management".

Information Management is a technology enabling the management and sharing of data or information among groups or functions providing information that is: Complete, Accurate, Reliable and Timely. This technology is an attempt to manage and support all aspects of a company's business (See Figure 3).

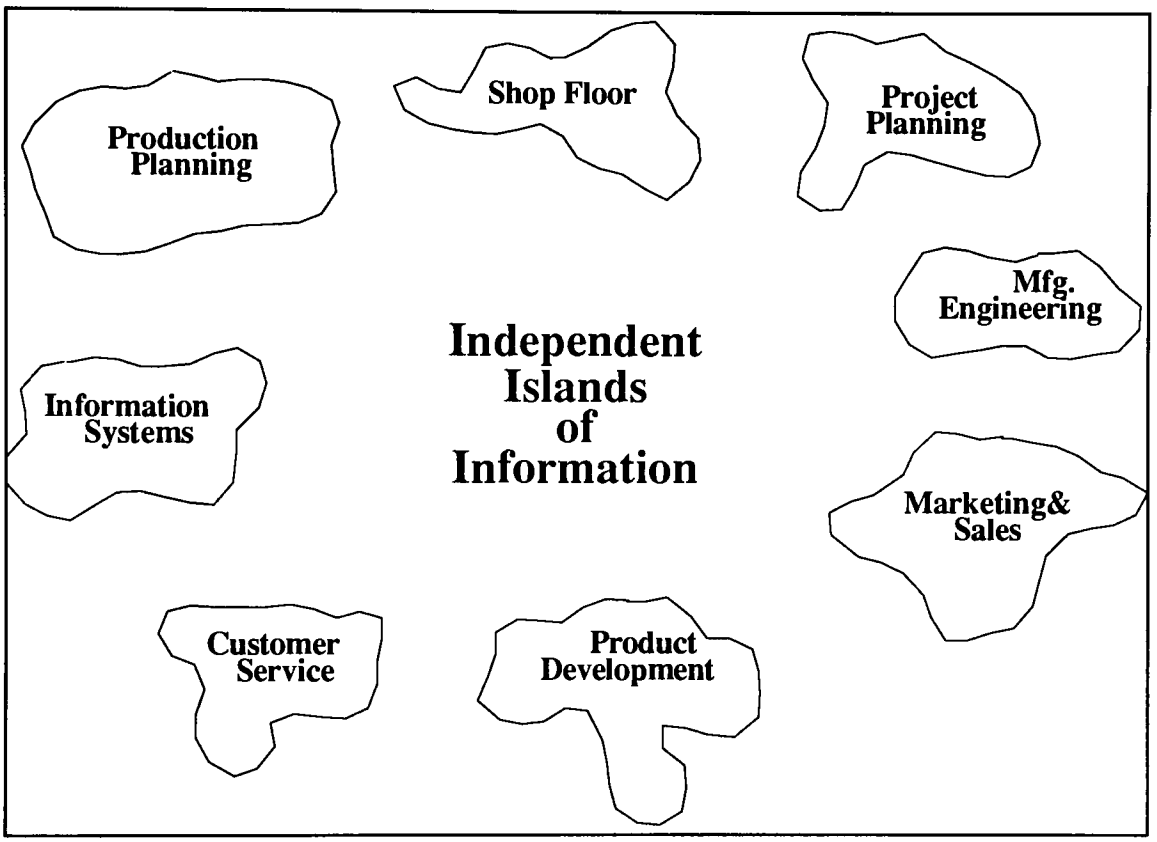

Figure 2. Islands Of Information

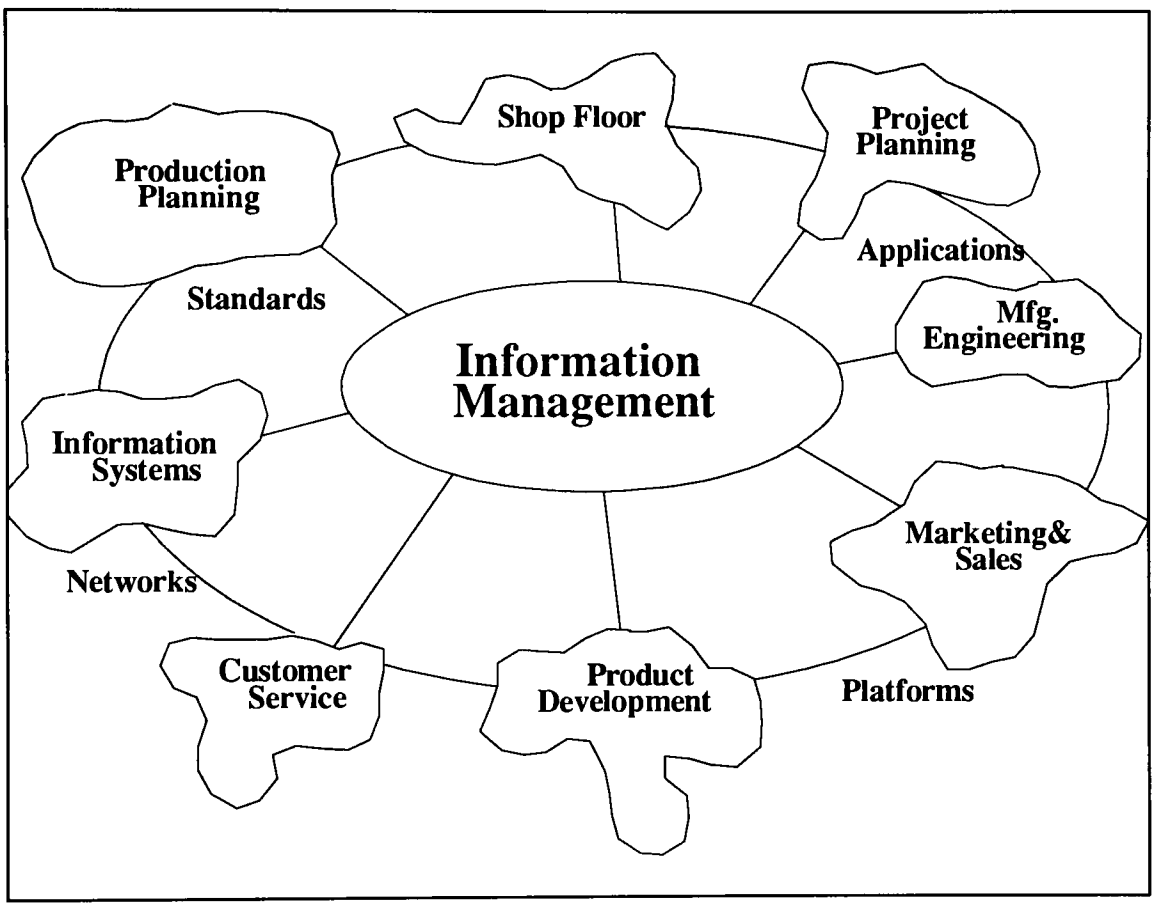

Figure 3. Information Management Encompasses All Forms of the Corporation[16]

Information Management also attempts to manage different tasks like ECO's, PCO's, Revision Control, and Concurrent Engineering.[17] There are three key elements to Information Management:

1.0 Document Management provides on-line revision handling, security and access control, documentation structuring, linking, markup management and external database query. Not only should the system control revisions of a document but also any proposed changes. Guaranteed integrity of multiple documentation versions and configurations is essential. This is a kind of electronic librarian. Today's corporations are also many times located in physically different locations. The information management system makes all forms of documentation or information accessible to all corporate sites.[18] E-mail capabilities are also essential for notification and communication between work groups and corporate sites.

2.0 Engineering Work Flow ensures that engineering documentation, on a time-critical path, is managed quickly and accurately. This controls or manages the documentation each step through the work flow controlling the list of users and groups who can access the information.[19] The system should allow you to model the flow to your requirements. E-mail, again, is essential for communication.

> **3.0 Document Processing** tools are required to provide the users with a convenient simple-to-use graphical interface so they can manipulate, revise and view documentation quickly on wide range of platforms.[20]

The rewards of document management and automated work flow are substantial. Implementing such systems can deliver a payback of 10-1 in a single department.[21] Also the amount of personnel required to complete a task can be reduced significantly by automating such tasks. Listed below are some of the other benefits of an Information Management system:

- The system organizes data to serve all disciplines of an organization.[22]
- It controls the storage and retrieval of files and associated attributes, enabling end users to quickly locate needed information amid a tremendous volume of data.[23]
- Network wide communications via electronic mail.[24]
- Graphical Interfacing.[25]
- Integrated Backup and Retrieval.[26]
- User definable attributes.[27]
- A quicker time of product to market through shorter development times. The data or information is available to foster concurrent work practices (this will be discussed later).[28]
- Improved quality of both product and operations.[29]
- Earlier problem identification and shorter change cycles. Production groups are closely linked with development activity.[30]
- Integration of existing environments and protection of current investments.[31]
- Information that is timely, accurate and pertinent which allows organizations to operate on facts, **NOT GUESSWORK!.**[32]

In some cases, accuracy and accessibility to critical information is now a mandatory requirement in order to comply with regulatory authorities or engineering practices. The next chapters will give a brief discussion of some of these regulations and engineering practices.

CHAPTER 2
COMPUTER-AIDED ACQUISITION AND LOGISTICS SUPPORT (CALS)

CALS is a large scale, long term information management project initiated by the U.S. Department of Defense the aim of which is to reduce the cost of supporting and maintaining military equipment.[33] SGML or Standard Generalized Markup Language is a part of the CALS program included in:

- MIL-STD-1840 The Automated Interchange of Technical Information
- MIL-M-28001 SGML
- MIL-D-28000 IGES (Initial Graphics Exchange Specifications)
- MIL-R-28002 CCITT Group 4 (International Consultive Committee on Telephony and Telegraphy)
- MIL-D-28003 CGM (Computer Graphics Metafile)

Any corporation that is involved with military support of any form must learn and becorne cornpetent with the CALS formatting in order to support their military involvement. This will also insure the corporation as a viable vendor to the government.

CHAPTER 3
STANDARD GENERALIZED MARKUP LANGUAGE (SGML)

SGML can describe and create documents that are not dependent on any hardware, software, formatter or operating platform/system. SGML allows you to manage information as data objects instead of characters on a page. This is a language for describing documents in terms of "What" not "How" and identifies objects according to their purpose or function.[34]

This is accomplished by "marking-up" the data in a certain way that is recognizable regardless of the systems used to create or view the data. What is Mark-up? The traditional definition is: "Marking-up" of typewritten text to give instructions for a typesetter or composition on how to fit the text on a page.[35] This type of mark-up is called "Procedural Mark-Up". Procedural Mark-up works only when the parties exchanging the documentation both have the same system. Also if Style Guidelines change, or you need to present the same information in a different format, massive re-keying is required.

SGML utilizes a "Generic" mark-up that describes the purpose of the text in a document rather than physical appearance on the page.[36] This is know as "Descriptive Mark-Up" (See Figure 4). Some of the benefits of utilizing this type of mark-up are.[37]

- Better access and navigation of information.
- Improved content and quality of documentation.
- Increased competitiveness.
- Lower product documentation delivery and distribution costs.
- Faster and easier import and export of source data or information.

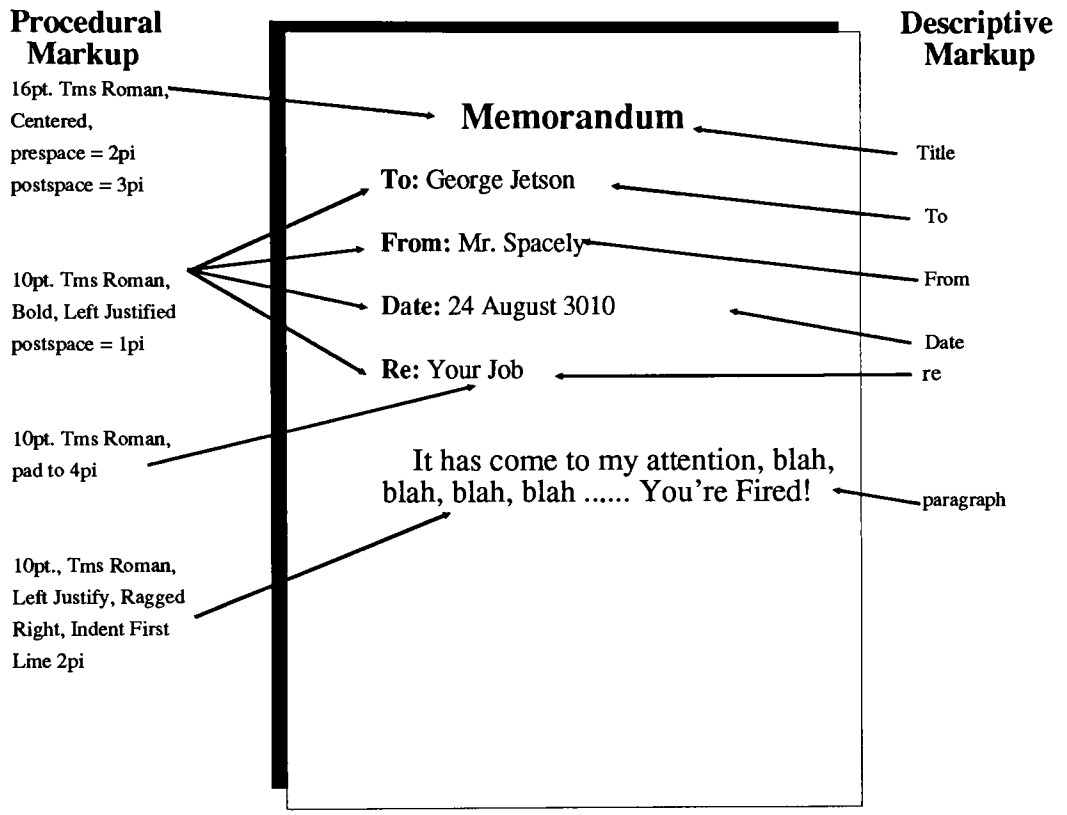

Figure 4, Procedural Markup vs. Descriptive Markup

SGML is an international standard (ISO 8879) published in 1986 and since SGML documents conform to an international standard, they are portable. This means you can exchange them seamlessly with users who have different systems.[38] SGML is also utilized by the following industries:

- AAA - Air Transport Association of Publishers
- ATA - Air Transport Association
- TCIF - Telecommunications Industry Forum
- DOD - United States Department of Defense
- (CALS) Computer-aided Acquisition and Logistics Support
- Commercial Airline Industry
- DOE - Department of Energy
- IRS - Internal Revenue Service
- Securities and Exchange Commission
- Open Software Foundation

CHAPTER 4
ELECTRONIC DATA INTERCHANGE (EDI)

EDI grew out of the work done by the Transportation Data Coordinating Committee (TDCC) during the 1960's and the 1970's. The committee was formed by private U.S. rail, air and water carriers to explore the computers ability to exchange information on freight movement. In the 1980's the U.N.'s Economic Commission for Europe developed EDI for Administration, Commerce, and Transport (EDIFACT), an international standard designed to serve all types of transactions across all borders. Although still evolving, EDIFACT has the backing of the Customs Agencies of the U.S. and European Economic Community. In 1987 the non-profit Data Interchange Standards Association formed the X12 Committee, whose tasks were to create a new data format based on the TDCC's work. This format, known as X12, was ratified by a the American Institute as an official U.S. Standard. The U.S. Federal Government has released the Federal Information Processing Standard (FIPS) 161 endorsing both the X12 and EDIFACT formats, asking all Federal agencies to support either by 1996.[39]

EDI is carried by VAN's (Value Added Networks) which operate as a store-and-forward system that is similar to E-mail. VAN's serve as the intermediary for the actual communication of electronic transactions among trading partners.[40] It can also produce faxes or other media for companies who do not have EDI capability. Although EDI is beginning to make its presence felt, it is still circumscribed by a number of difficulties, including platform-specificity.[41] Figure 5 demonstrates the file format of a typical EDI data file.

Sample Invoice

Remit To: Smith Corporation (Selling Party)
900 Easy Street
Big City, NJ 15455

Ship To: The Corner Store
501 First Street
Crossroads, MI 48106

Charge To: ACME Distributing
P.O. Box 33327
Anytown, NJ 44503

Terms of Sale: 2% 10 days from invoice date

Mail To: Accounting Department
co Jones (618) 555-8230

Formatted Into X12 Standard

N1\SE\SMITH CORPORATION/L

N3\900 EASY STREETN/L

N4\BIG CITY\NJ\15455N/L

N1\ST\THE CORNER STOREN/L

N3\501 FIRST STREETN/L

N4\CROSSROADS\MI\48106N/L

N1\BT\ACME DISTRIBUTING CON/L

N3\P.O. BOX 33327N/L

N4\ANYTOWN\NJ\44509N/L

ITD\01\3\2\\10N/L

PER\AD\C.D.JONES\TE\6185558230N/L

Figure 5. Comparison of Standard Invoice vs. EDI Data File

CHAPTER 5
CONCURRENT ENGINEERING

Concurrent Engineering is a systematic approach to integrated product development that emphasizes response to customer expectations and embodies team values of cooperation, trust and sharing. In the development of a product in today's marketplace, short lead time and superior quality are becoming a major corporate goal to maintain competitiveness. Concurrent Engineering's decision making process begins with extended periods of parallel effort that is synchronized with comparatively short exchanges between participants to produce a consensus.[42] This form of engineering structure develops a layered architecture of technologies that enable a "Virtual Team". The layers as diagramed in Figure 6 are:

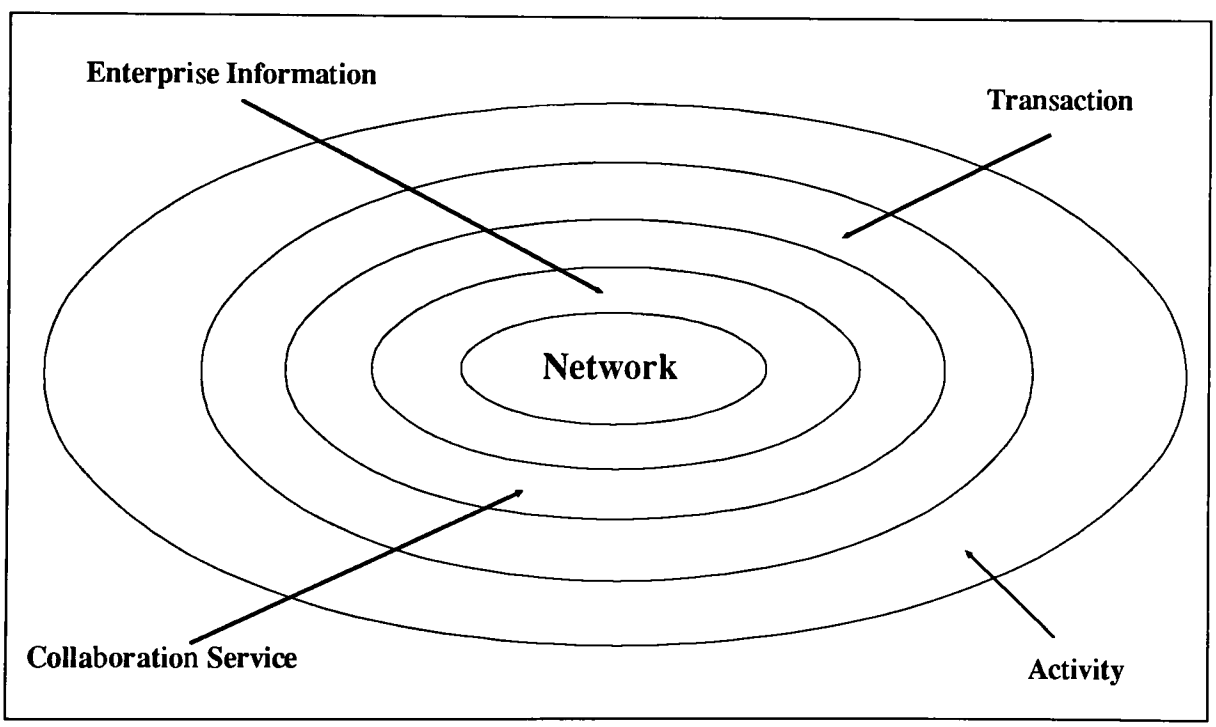

Figure 6. The Layers of Concurrent Engineering

- **Activity Layer** - The activity layer takes the virtual team in a continuous cycle of:

    - Planning
    - Implementing
    - Monitoring
    - Improving
    - The Collection Of Activities Vital To A Product

- **Transaction Layer** - In this layer each team member of the virtual team completes fundamental tasks. It is this layer where the conclusions of this paper will take form to add value to the corporate enterprise. These tasks are:[43]

    - **Lookup** - Throughout the corporate structure information is scattered on different media. The team members require an "Information Server" that provides a single point of inquiry.
    - **Compute** - Through computation the information from the "Lookup" task has value added.
    - **Communicate** - Sharing information is key. Limitations in today's band widths of networks and various media severely hamper the efficiency of this task.
    - **Negotiate** Concurrent Engineering is predicated on the ability of each virtual team member to negotiate with the group and reach a consensus.
    - **Decide** Various decision-making tools are required by different members of the virtual team during the course of product development. Most of the tools in use today are centered on single perspective. There is a "need" for investigation, advancement and deployment tools to assist the Group Decision Making in the areas of:

        - Group Decision Support
          Design Assessment
        - Quality Functions

    - **Archive** Once the product is realized it should be captured and subsequently exploited while going through redesign or development of related product or products. Much development is warranted to constructing a "Hypermedia-Based Electronic Notebook" to replace the current paper process.

- **Collaboration Layer** - This layer is the service layer performed by the system developed to enhance the Concurrent Engineering practice. These functions include:[44]

    - Collection Coordination
    - Information Sharing
    - Integration

- **Enterprise Information Model Layer** - The availability of all information is crucial to any Corporate Enterprise.[45]

- **Network Layer** The foundation of the Virtual Team is the Network Layer. It provides Directory Services, Interprocess Communication, and Remote Procedure Calls. Advances in todays network capabilities will insure a flow of more reliable and timely information to enhance the Concurrent Engineering practice.[46]

As mentioned before the need for multi-platform documentation management systems is required by practically every type of corporate venture. Software vendors and system integrators are responding to that need. In 1991, the top 100 ISV's (Independent Software Vendors) spent $570+ million on product development. Over 80 percent of these companies develop products for multiple platforms and the trends continue to grow.[47] From a study conducted by International Data Corporation, an average 5 percent rise in Information Services departments budgets for 1992, compared to 2% in previous years. These trends were found to be parallel in other countries where France and the United Kingdom growths in multi-platform applications would range between 5 and 6 percent.[48]

The trend toward multiplatform environments is also seen by announcements made by major development corporations. An announcement made by Apple Computer, Inc. and IBM Corporation that they will work together to create a new cross-platform environment (code named "PINK") speaks directly to this trend.[49] Companies like

Digitial Equipment Corporation have introduced products like Desktop ACMS which enables software applications to perform on all desktop devices and platforms in a company.[50] Adobe's "Carousel" technology, now known as "Acrobat", will allow users to take a postscript document and compress it to develop a portable file format called a PDF (Portable Document File). The read-only postscript document can be viewed on Macintosh systems, DOS based systems, and UNIX platforms without requiring data file format conversion.[51] Many other developers of both software and hardware have introduced applications to be used to integrate computer data on multiple platforms allowing the corporate enterprise to become that much closer to "Real Time Total Information Sharing".

CHAPTER 6
THE PROCEDURE

As a team, the corporate enterprise can end the paper chase, first by converting paper documents into electronic images (if the data does not already exist) and then by changing old paper-based systems and processes to take advantage of the tremendous efficiencies of electronic document management. This will change current serial work flow practices into a more automated parallel process for managing documentation. When starting a project that will possibly change the documentation management process across the business, develop a pilot project within a specific department or function. Try to limit the project to a six month implementation. Don't try to tackle the entire business in one project. This will make the development of new processes more manageable and provide more timely feedback to management. Although you are targeting a single process or department, always keep in mind a total company strategy. Although the master plan will be too complex to implement immediately, it will serve as a road map for future projects.

The ECO/PCO process has been reviewed before many times to try to improve the process, with little or no success. This time the processes that will be utilized to conduct this study are taught during the company's Quality Education System (QES) which is a program or approach to quality taught by Phillip Crosby and Associates of WinterPark, Florida. This process has a four major step configuration called the "Prevention Implementation Model". One of the key reasons this process was utilized was that in each of the four steps there is constant review, and if a bottleneck appears you may "Loop Back" to retarget the project or make a decision to proceed. The four steps are shown in Figure 7.

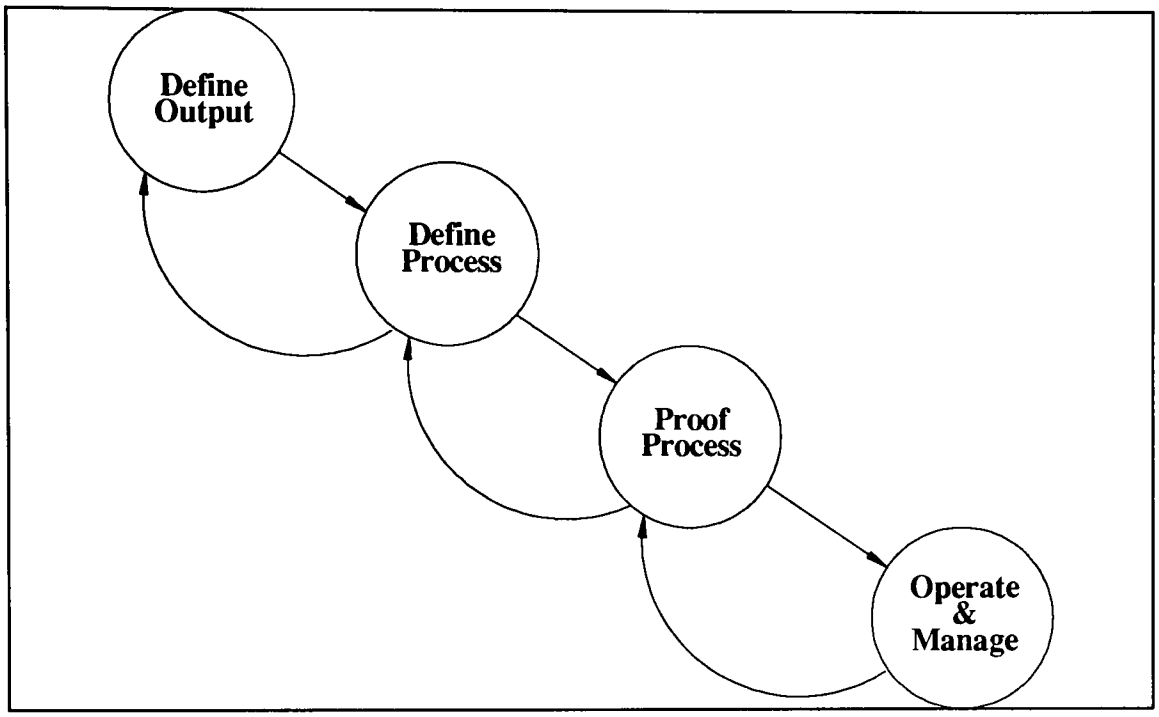

Figure 7. Prevention Implementation Model[52]

Each of these four major steps have many associated sub-steps:

- Stage A - Define Process
    - Step 1: Preliminary Definition
    - Step 2: Output Requirements Definition
- Stage B - Define Process
    - Step 1: Overall Process Definition
    - Step 2: Subprocess Definition
    - Step 3: Integration and Validation
- Stage C - Proof
- Stage D - Operate and Manage
    - Step 1: Full-Scale Operation
    - Step 2: Continuing Process Management

Core Team

The first step in the QES process is develop a Core Team and train them in what the company calls QESII training which is Prevention Implementation. The core team was represented by individuals with key positions that relate to the ECO/PCO function. They were:

- ECO Administration
- Software Release Engineering
- Software Process Engineering
- Development Operations
- Manufacturing Process Engineering

The first action of the core team was to complete a form called a "Process Model Worksheet". This worksheet, once completed, determined the customers and suppliers of the process along with their requirements. The model also determines other aspects of the process such as Performance Standards, Procedures Required, Facilities and Equipment, Training and Input Requirements (See Figure 8). The Process Model Worksheet is an overall requirement listing and requires more in depth investigation into actual or more defined requirements.

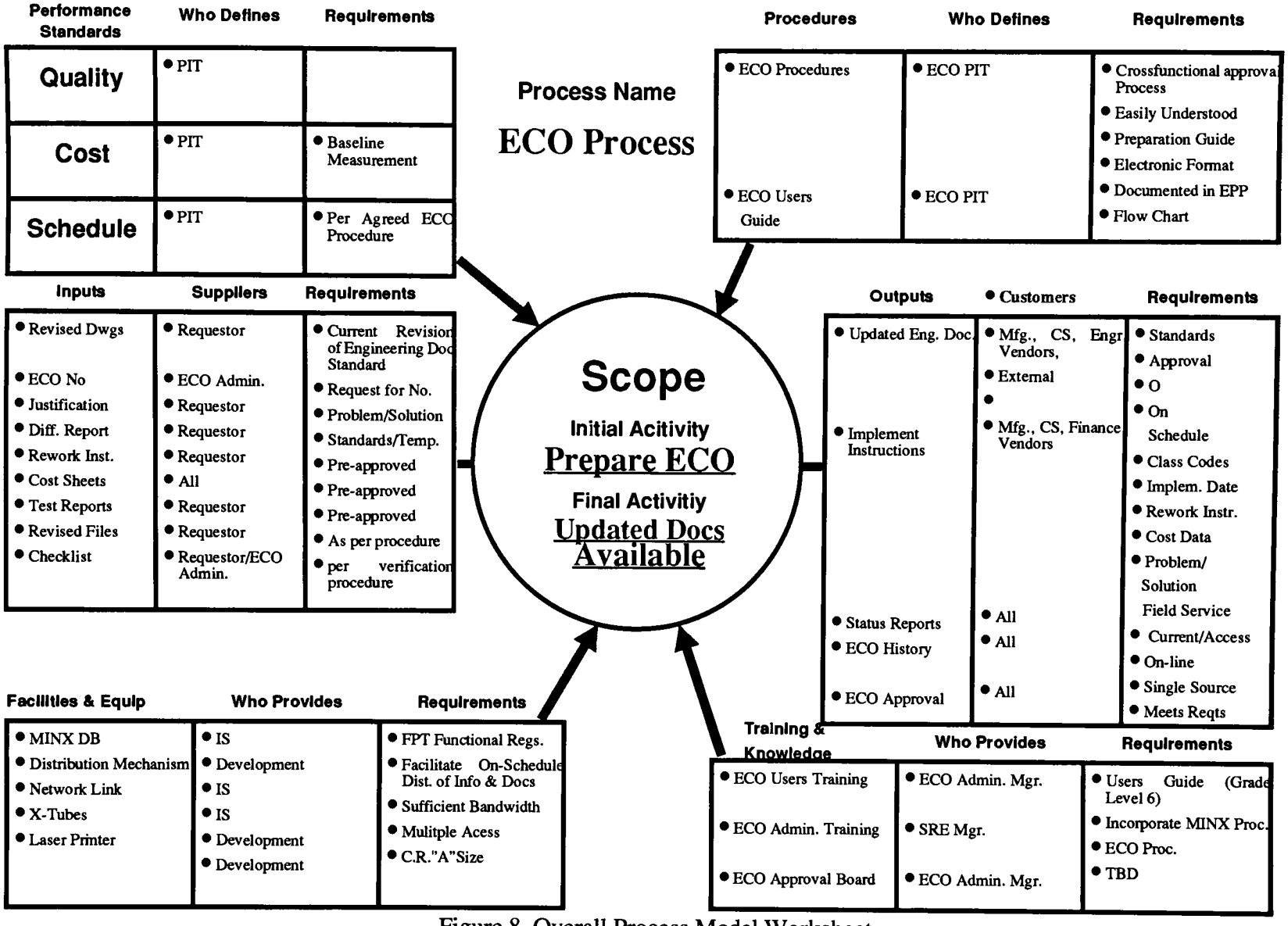

Figure 8. Overall Process Model Worksheet

Overall Process Team

Once the core team developed the Process Model Worksheet, an Overall Process Team was put together represented by the following corporate functions:

- Hardware Engineering
- Software Engineering
- Records Management
- Manufacturing Engineering
- Customer Services
- Technical Publications
- Product Management
- Mechanical and Subassembly Engineering
- Purchasing

The purpose of the Overall Process Team was to document the current ECO/PCO process and, by the customer requirements developed by the Process Model Worksheet, develop a proposed process to meet these requirements. Some of the major problems discovered during developing the current process model were (See Figure 9):[54]

- Too many reviews/inspections:
  - 6 Decisions Loops
  - 5 Delays
  - 5 Review Points
- Too Many Delays (Due to Travel/Transportation of Paper Documents for Review)
- No distinction between preparation and approval.
- Too little understanding of process (Communication and Training).
- Different every time
- Must "PUSH" changes through the system.
- Ownership of the process was unclear.
- Batch movement of documents in serial process.

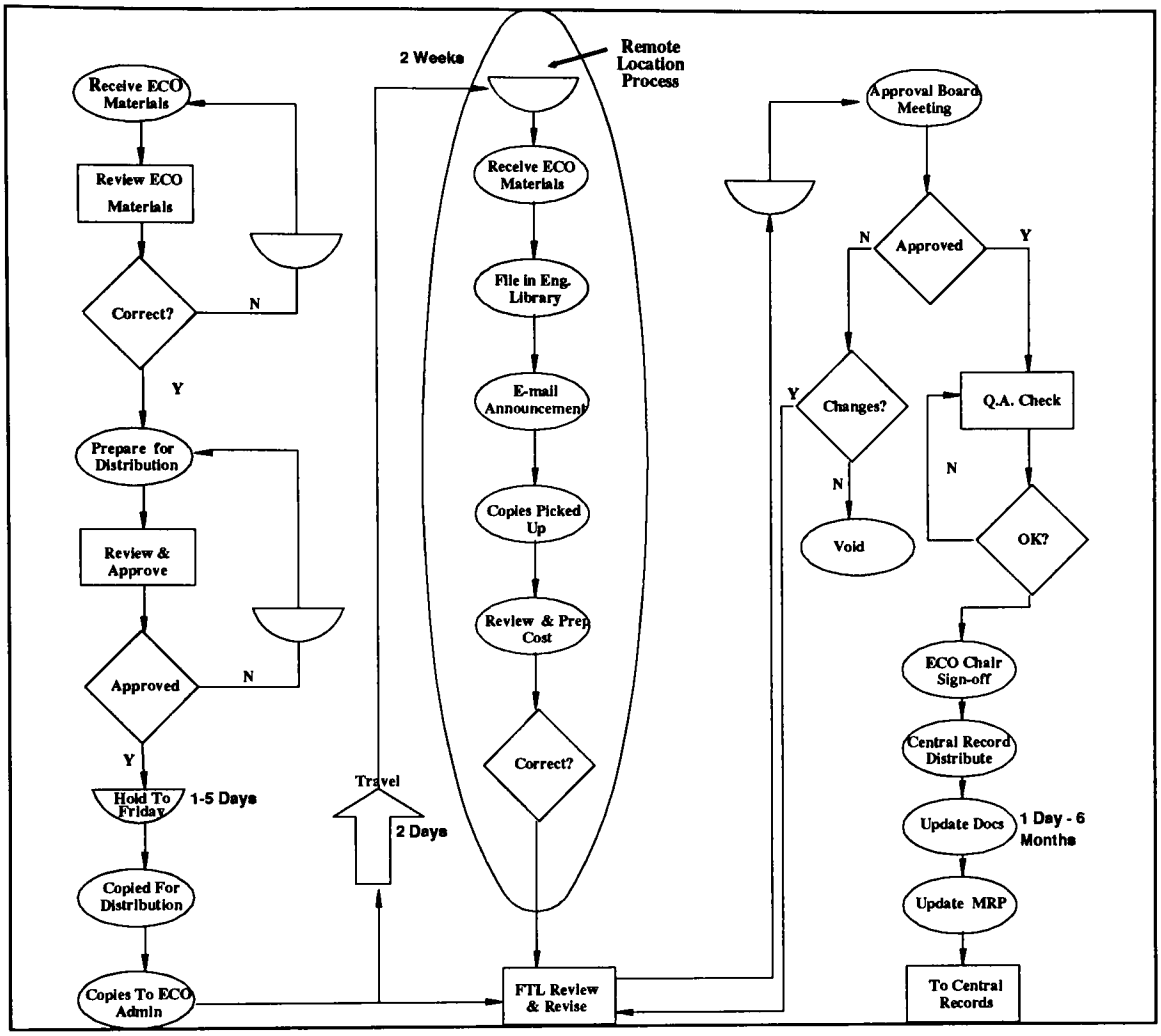

Figure 9. Current Process Flow Including Multiple Site Locations

Once the current process was documented and the problems analyzed, an action plan was developed. The steps were as follows (See Figure 10):

- Develop a clear distinction between "Preparation" and "Approval".
- Identify and define "Preparation Subprocess" as input to approval.
- Shift responsibility to create "Pull" process instead of a "Push" process.
- Set up a system to allow "Mapping" of subprocess timeliness.
- Make use of new technologies.
- Develop a system to facilitate "Flagging" of problems.
- Develop a system to facilitate greater communication.

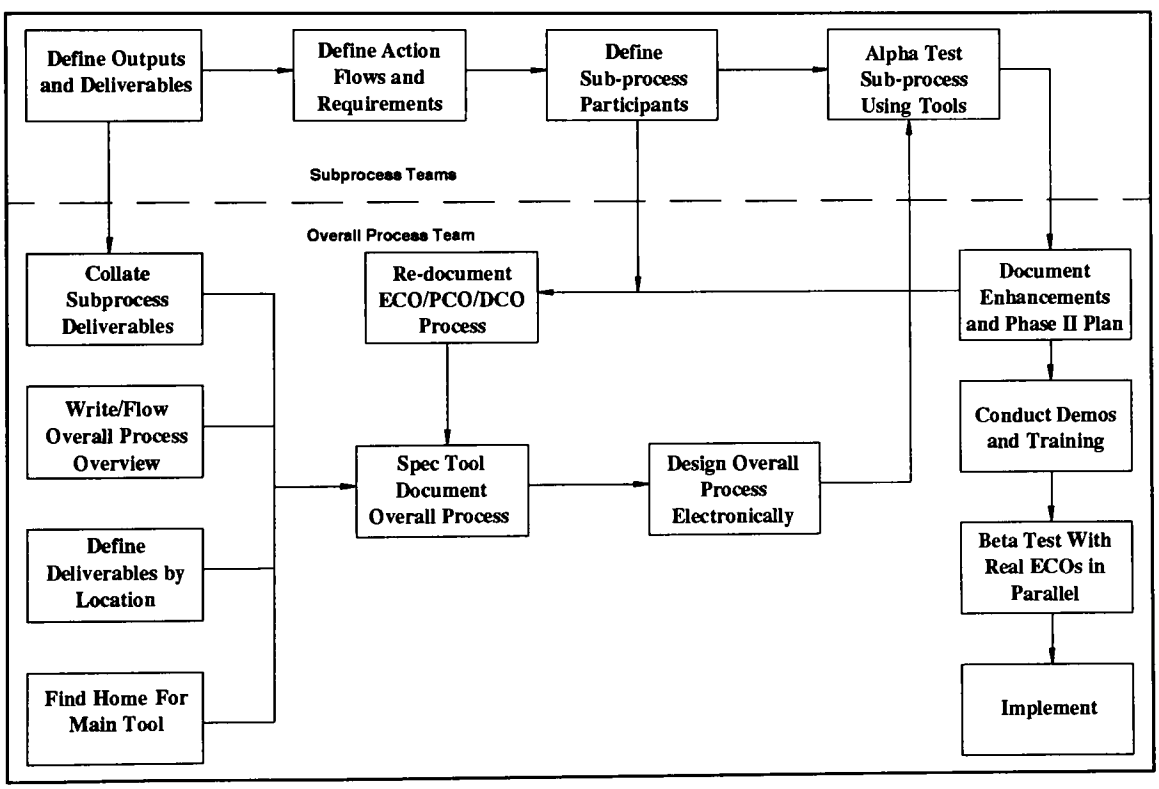

Figure 10. Generalized Action Plan[56]

The Overall Process Team's next task was to develop a proposed overall process (See Figure 11). As you can see the proposed process was developed with significantly less delays and reviews. Following is a comparison:[57]

Old Process	New Process
6 Decision Loops	1 Decision Loop
5 Delays	0 Delays
5 Review Points	2 Review Points

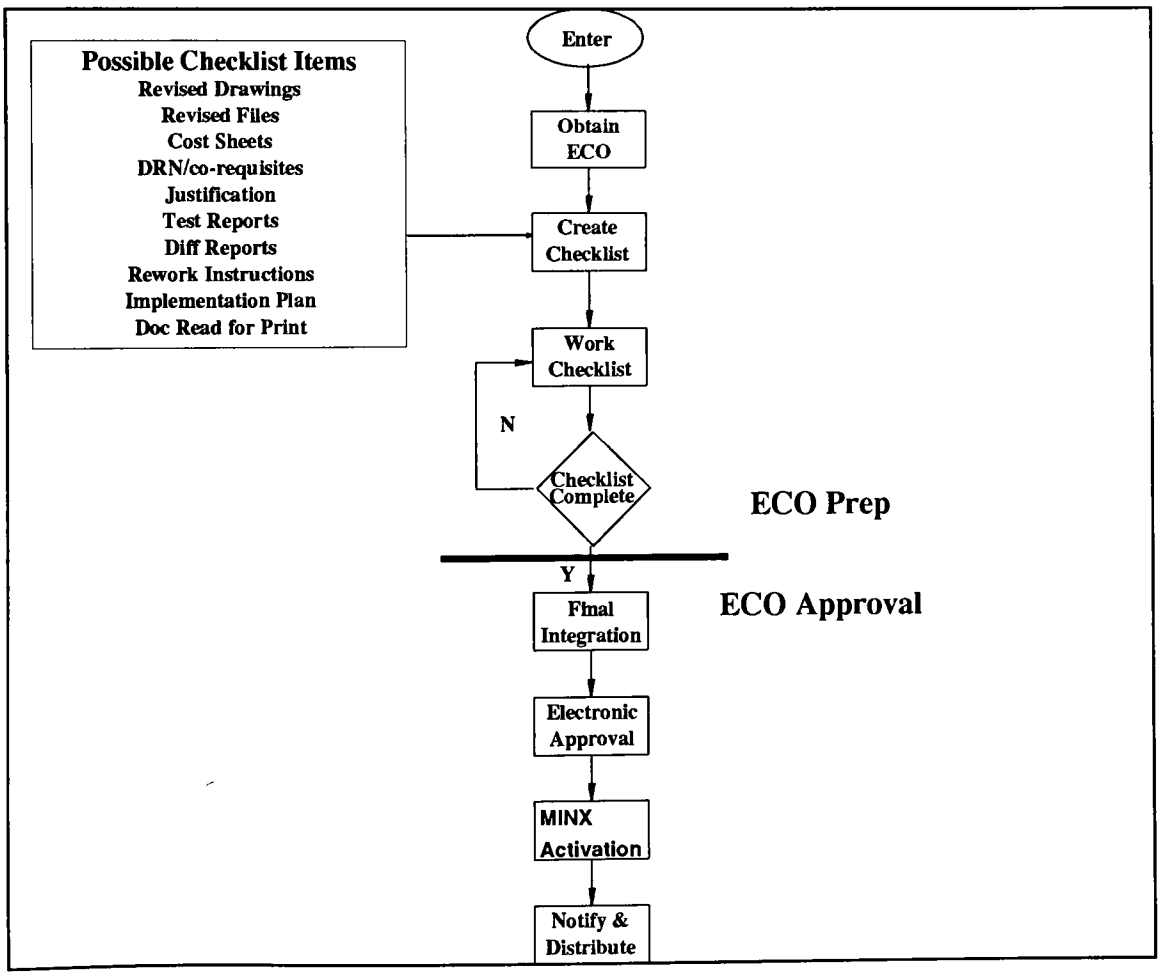

Figure 11 Proposed Process Overview

As you can see the proposed process takes the majority of the current process steps and, by utilizing on-line systems, converts them into a parallel or concurrent effort. This has become known as a "checklist" of activities. In the current process a copy of each document required for the ECO/PCO was combined together to create a "package". This package was physically marked-up and, after approval, the documents were updated and incorporated into the various systems utilizing the information.

In the proposed process the documents would be changed during the "checklist" phase and, and after approval, be incorporated into the systems or be "released". Being all documentation would be available on-line, time for processing an ECO/PCO would be greatly reduced due to elimination of physical transportation of paper documents.

Subprocess Teams

Once the proposed process was developed, "Subprocess" teams were created for each internal supplier to insure that all current input requirements were captured during the initial process model worksheet and process models. Each subprocess team was asked to develop a process model of the current process including definitive points such as what types of data files were created and the equipment (both hardware and software) were utilized. The subprocess teams were:

- Manufacturing Specifications
- Mechanical Assembly Specifications
- Components Specifications
- Product Documentation
- Software Specifications
- Circuit Board Specifications

The various hardware and software applications utilized by the various department are listed in Table 2. Also it should be noted here that each corporate site (not necessarily sales offices) is linked together utilizing ethernet network systems. The two major corporate sites, Manufacturing and Corporate Headquarters, were linked together with a dedicated "T1" link. Each of the systems noted in Table 2 has the capabilities of accessing this network for the transfer of computer data.

Table 2 Current Hardware and Software Applications

Hardware Utilized	Operating System	Software Application	Output Capabilities
Sun Sparc	SunOs 4.1.3	Cadence Concept	HPGL, Versatech Greensheet, Postscript
Sun Sparc	SunOs 4.1.3	Cadence Allegro	HPGL, Versatech Greensheet, Postscript, Gerber, Conversion to .DXF, Calcomp, Houston Instruments
DEC PDP-11	RSX	Cadence Telesis	HPGL, Gerber
Sun Sparc	SunOs	AutoCad	.DXF, .DWG, HPGL, .SLD, .IGES
Sun Sparc	SunOs	Medusa	HPGL
P.C. Compatible	MSDOS 5.0	AutoCad	DXF, .DWG, HPGL, .SLD, IGES
P.C. Compatible	MSDOS 5.0	Ventura Publisher 4.1	HP, Postscript
Macintosh	MacOs	Word Processing	Postscript
Encore 91	880pen	MINX, ASCII Docs	ASCII

Technology Team

Along with the development of subprocess teams, a team was developed to investigate the current technology available on the market in the area of document management. There were three basic options to document management for this company. The first was to develop, "in-house", all the systems or programs required utilizing all the current hardware and software. This would require large amounts of manpower in programming time. The second option is to buy available software and integrate the software into our existing hardware. Third, hire an integrator who would review our current process, suggest solutions and implement the solutions. Prior to making any decision, a study was done into the current technologies available for Document Management. The team developed key elements or characteristics of the system. The following are descriptions of these key elements.

1.0 The system must be a type of electronic vault or library with the capabilities of accessing different databases in different locations.

There are pros and cons to having either a centrally located database, meaning all the data resides on a single piece of hardware, and remotely located databases where the data would reside on the originator's application hardware. If all the data resides on a single piece of hardware, the act of "backing-up" of the data becomes a single task which can happen at scheduled times without the requirement of more than one or two personnel. If the data resides on numerous pieces of hardware the back-up of these databases requires numerous personnel and becomes

procedural as far as scheduling the actual back-ups. The more personnel and tasks involved, the more prone the process is to error.

2.0 The system must be able to transport, over a network, different forms of data developed by the sub-process teams. Original data must remain in the native format of the software application utilized to create the data. The data may or may not be converted to another format for the review or view processes. The original formats, especially computer aided drawing are usually in vector format which are extremely large files. Transferring these files through the network for review or view purposes would slow the networking operation so many time the original drawings or files are converted to a raster or bitmap image which greatly reduces the size of the data file.

3.0 System security and access control must be maintained. Different revisions of documents must be maintained and only approved documents available to the general corporate public. There must be no chance of an unapproved version of a document being utilized in any of the corporate functions which could severely affect the quality of the product or service. Security must also be maintained. Persons outside the company must not be able to access any form of the computer data unless given access. Not just security to the system but also privileges to individual documents must be programmable in the software system chosen. This type of security would be given to outside individuals or firms such as vendors and to individuals in the actual ECO review process.

4.0 The system must have the ability to program a work flow process to systematically and electronically move computer data through an approval sequence. Each operation in the work flow sequence must be automatically time and date stamped for both access and completion. This is very important for trackability and traceability. After the updated process is developed by the different teams, it will be programmed into the software system which will route all the pertinent data in the correct sequence. The following is an overview of how the data may be routed:

4.1 An ECO request would be generated. The responsible parties would log into the system and access the current revision document or documents and generate the updates required. The system would also compile a list of other affected documents and/or other requests for a change utilizing other forms of communication tools than the ECO/PCO function. This would insure that all changes that were required to the document would be completed in a single approval cycle.

An important point arises at this stage of the ECO process if it is to be handled electronically and as paperless as possible. What if a data file is being utilized by one ECO package and another ECO package is initiated for a different part but affects the data file used in the other ECO package? The system must undeniably alert the

concurrent users of a certain data file that the file is being utilized in other ECO packages.

4.2 After the responsible party updates the data, the data would be placed into the system which would notify the reviewing parties in the next step of the approval process. Each party in the process would review the documentation electronically and add any comments or redline any changes utilizing their respective hardware. The system would attach electronically the comments or redlines, if any, to the documents to be reviewed by the originators of the changes or any other function in the process. If there were no changes to the document, the reviewing functions would "sign-off" or approve the documentation electronically and the system would automatically notify, through the use of electronic mail or e-mail, the next step in the process of the documentation changes.

4.3 Once the documents were issued to every step of the approval process, and each participant accepted the changes, the document's revision would be fixed. Any other changes to the document from this point would create a new revision of the document. With the revision fixed, all the other databases would be notified either electronically or through the responsible database administrative functions to be updated. This would include Bills of Materials in the MRP system, manufacturing

processes, quality organizations, vendors and any other functions utilizing the data. Again the system should have the capability of programming these functions by the type of document to be changed.

5.0 Being a mainframe computer manufacturer, the company's first choice would be to purchase a system or develop a system that would run on the company's own platform, which is an 88Open platform. If a system could not be found or a system is discovered with all the correct functions, the use of another system as a server to the network retaining all the data on the company's own hardware has not been ruled out.

6.0 Each department or function within the corporation currently is operating with different hardware and software applications. The proposed system must be able to operate on each of these currently installed systems.

Next a matrix was developed to use the review of currently available software applications (See Table 3). In this way all the criteria required for the corporate process could be reviewed consistently. Also the complete review of all attainable literature on the subject of Information Management was conducted, including periodicals where the majority of the information was obtained. Seminars were attended and general inquires were put out to the public for Information Management systems. Demonstration packages were received and reviewed along with product literature on many software packages.

As the investigation progressed, one point became obvious. Not all software that pronounces to be "multiplatform" will necessarily work on all your in-house platforms. Some will work on the Personal Computer and Macintosh platforms but not on the UNIX or X-window platforms. Also some vendors tout that their software packages will operate in an Unix environment, but there is so many variant forms of UNIX today that it may not run on your particular platform or operating system. This is where testing comes into play. Always ask for a demonstration disk or tape of the software application to insure compatibility.

Another discovery was also made during the investigation of software packages on the market. There was no "one" single software application that met all the requirements of our corporate process. Choices had to be made on which software packages would complete which part of the process the best. This added another variable into the development, the compatibility of not just software and hardware was a concern but the compatibility of different software packages being utilized together or inline.

Table 3. Attribute Matrix of the Top Three Reviewed Packages

Attribute	Package A	Package B	Package C
Available on Multiple Platforms?	Yes	Yes	Yes
Unix (X-Window)	Yes	Yes	Yes
SunOs	Yes	Yes	Yes
PC DOS	Yes	Yes	Yes
PCOS/2	No	No	No
MacIntosh	Yes	Yes	Yes
88Open	No	No	No
Other			
Comments			
Platform Interfacing			
With Conversion (External)			

Table 3. Continued

Attribute	Package A	Package B	Package C
Without Conversion (Internal)	Yes	Yes	Yes
Programmable Workflow	Yes	No, But About To Be Released	Yes
Markup Capabilities			
Annotate	Yes, With Optional Package	Yes, Internal	Yes, Internal
Redlining	No, Available Next Release	Yes, Option	Yes, Option
View Only Packages Available?	Yes	Yes	Yes
Input File Formats?			
Native, Without Conversion	Yes, For View Package, No For Workflow	Yes, For View & Redlining	No
File Import, Conversion Required	To Utilize The View Package For Workflow	No, But The Capabilities Exist	Yes, Raster Image Required
Comments	In order to use the work flow with the view package, a third proprietary document creation package is necessary		
Native Master File Edited At Any Time?	No	No	No
Customization Capabilities			
Macro Capabilities	Yes, With Tool kit	Yes	Yes, With Tool kit
GUI's or Window	Yes	Yes	Yes
Document Linking	Yes	Yes	Yes

Table 3. Continued

Attribute	Package A	Package B	Package C
Documentation Supported			
Text Formats- ASCII	Yes	Yes	Yes
Line Art - Vector	Yes, With Conver.	Yes	Yes, With Conver.
Images - Raster	Yes	Yes	Yes
Database Files	Yes	Yes	Yes
Document Linking	Yes	Yes	Yes
Output Capabilities			
Printers	Yes	Yes	Yes
Plotters	Yes	Yes	Yes
Color	Yes	Yes	Yes
Sound	Yes	Yes	Yes
Video	Yes	Yes	Yes
File Formats For Other Software Applications	Yes, With Conversion	Yes, With Conversion	Yes, With Conversion
Compliant To Standards			
CALS/JCALS	Yes, With Filters	No	Yes, With Filters
ISO (File Format)	Yes, With Filters	No	Yes, With Filters
EDI	Yes	No	Yes
E-mail Support	Yes	Yes	Yes
Programmable Permissions?			
System	Yes	Yes	Yes
Document	Yes	Yes	Yes
Central or Local "Vaults"	Both, Definable	Central Only	Both, Definable
Revision Control	Yes	Yes	Yes

Table 3. Continued

Attribute	Package A	Package B	Package C
Support?			
Training Available	Yes	Yes	Yes
Implementation/Integration	Yes	Yes	Yes
Technical Support, How? Phone, E-mail, On-Site, etc...	Yes, All	Yes, Phone, Onsite	Yes, All

The matrix was completed and top two software packages were chosen for a more in depth review. Each manufacturer was asked to set up a demonstration utilizing their own equipment for the team leaders of the subprocess teams. After reviewing both packages, "Package A" was chosen as the software application to be utilized if outside applications were to be procured. Certain aspects of this package and manufacturer appealed to our company. First, the different options such as the view package could be purchased and utilized individually which meant a staggered implementation could be introduced. Second, the manufacturer seemed to be well versed in the UNIX platform arena where some of the other manufacturers where just getting acclimated. This brings up an important question. None of the manufacturers reviewed had their software applications available on our 88Open platform. Would we need to buy a new piece of hardware to support this software package? It was suggested that we introduce a staggered implementation utilizing those parts of "Package A" software package, meaning the view and conversion utilities that will operate on our current in-house hardware and set up a strategic alliance with the manufacture to port his applications to our platform. This would be beneficial to both parties as our company would be

marketing the software application as an option to our customers and the software manufacturer could support other hardware systems not currently supported.

Next, a demonstration was developed for the Overall Process Team along with management personnel at the corporate offices. Following where considerations when setting up the demonstration.

Workflow - With the assistance of the manufacturer, the software application was programmed to imitate the proposed process which would, during the demonstration, relay on to the attendees a more "real life" scenario on which to base their decision.

Document Types - Again, to try to present a more real life scenario, a collection of actual documents in the actual file types were collected and input into the trial software application. This way the attendees could visualize how the application would handle different file types such as ASCII files, CAD drawings, and document publishing files.

Hardware - Even though the software applications did not run on an 88Open platform, they did operate on the SunOs platform which our company utilized in house. These pieces of hardware would not be the ideal system as our current mainframe product would be far faster for distributing and managing the files. It was decided to conduct the demonstration on the one of our inhouse pieces of hardware to demonstrate that if a decision was made to set up a strategic alliance with the manufacturer, during the porting developing time our company could utilize the software applications.

The actual setup of the demonstration was schedule for a specific time when all the decision makers were available. Prior to that time, the software was loaded onto our hardware along with the various documents files to be utilized during the ECO/PCO process. The work flow was programmed in and the software applications were run to insure no "bugs" or problems would develop during the demonstration. This is

important. The demonstration must run clean to install the proper impressions into the decision making personnel.

The demonstration was conducted as an open forum with questions and concerns being responded to immediately. It was well attended and all personnel were prepared to diagnose all aspects of the software applications with regard to our corporate strategies.

What about the current paper drawings or documentation which do not have an associated electronic data file? An outside source to facilitate the scanning of current paper documentation was developed to convert the documents to an electronic source. The decision was made after reviewing the quantities of "paper-only" files that may be introduced into an ECO/PCO and the costs of purchasing a quality document scanner that would meet our requirements versus the cost to have an outside vendor complete the tasks.

CHAPTER 7
RECOMMENDATION

After reviewing off-the-shelf software applications, it is recommended that the company utilize "Package A" in a staggered implementation manner as follows:

Phase I

First, utilize in-house programmers to develop a basic on-line communications package to initiate personnel to electronic communications and systems rather than paper. Certain aspects of the proposed process can be completed electronically with very minimal programming, instruction, and training such as:

- Notification of ECO/PCO packages
- Review Notes
- Approvals

Second, a view package should be procured to facilitate the viewing or printing in remote locations of documentation. The viewing application of "Package A" should be procured as to insure compatibility with future integration of other software components. Since our own in-house programming effort will not accommodate the actual transfer and viewing of documents, a standard output file format should be utilized. There will actually be more than one standard to insure all current software application files could be viewed. Suggested file formats are in Table 4.

Table 4. Suggested File Formats

Application	File Format
Vector - Line Art	*.HPGL
Word Processing or Desktop Publishing	*.PCL
MRP	ASCII

Third, create a strategic alliance with the software vendor to port its software applications to our native 88Open platform which would be beneficial to both companies. Discussion should be initiated on how to develop the ported version, costs to do so, and a time line for completion. At the same time, a review of current in-house hardware should be conducted to determine if a system exists that could be utilized as a server while the porting operation is being conducted. The system should be capable, in terms of speed, to manage the volume of documentation created during the ECO/PCO process. This would be an analytical test to insure system functionality for future applications such as the Release process, Manual Documentation, etc.. During this time the software application's shortcomings and any major pitfalls could be discovered and remedied prior to future phases, moving toward full system startup. All data files and the operating database utilized by the software application could reside on our native platform to insure speed and backup facilities.

Training of a select group could be facilitated during this pilot program. This makes the process of integration, training, and support more manageable for the vendor and our in-house Information Systems department which would be supporting the integration.

Investigation of future hardware requirements should be developed during this period to distinguish those personnel who reviewed the documentation as a paper process who will require some form of viewing aid (hardware) and printing capabilities. Once the documentation is in an electronic file format, other functions will require viewing capabilities such as the Quality Assurance organization to perform audits. Certain vendors should also be selected for a pilot program of accessing the data electronically in leu of receiving paper updates.

Last, the "State of Mind" must be changed from a batch serial process to a single operation, concurrent process. This may be the hardest action to complete as many personnel have structured their own internal process with a certain time and day to review the ECO/PCO material. Personnel will require retraining and need be well informed of the benefits of an "On-Line" or "Paperless" system and how it could improve their own internal process.

Estimated software costs for Phase I utilizing in-house hardware for the network server (not our native platform) is $60,000.00.

Benefits

- Again, in the computer industry, "Time To Market" is extremely important and with total integration of an Information Management system, time will be greatly reduced due to the elimination of transporting paper document packages.
- Labor and material costs of processing the paper to construct the numerous paper ECO/PCO packages will also be diminished from the current volume.
- There will be a closer link between the various corporate functions to insure shorter development times.
- There will be a reduction of ECO/PCO activity.
- Information that is utilized by the various corporate functions will be more timely, accurate and allow the functions to operate on facts, **NOT GUESSWORK!**

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